

# Surface Biology and Geology



## Mission Overview

2023 NASA Carbon Cycle and Ecosystems Joint Science Workshop

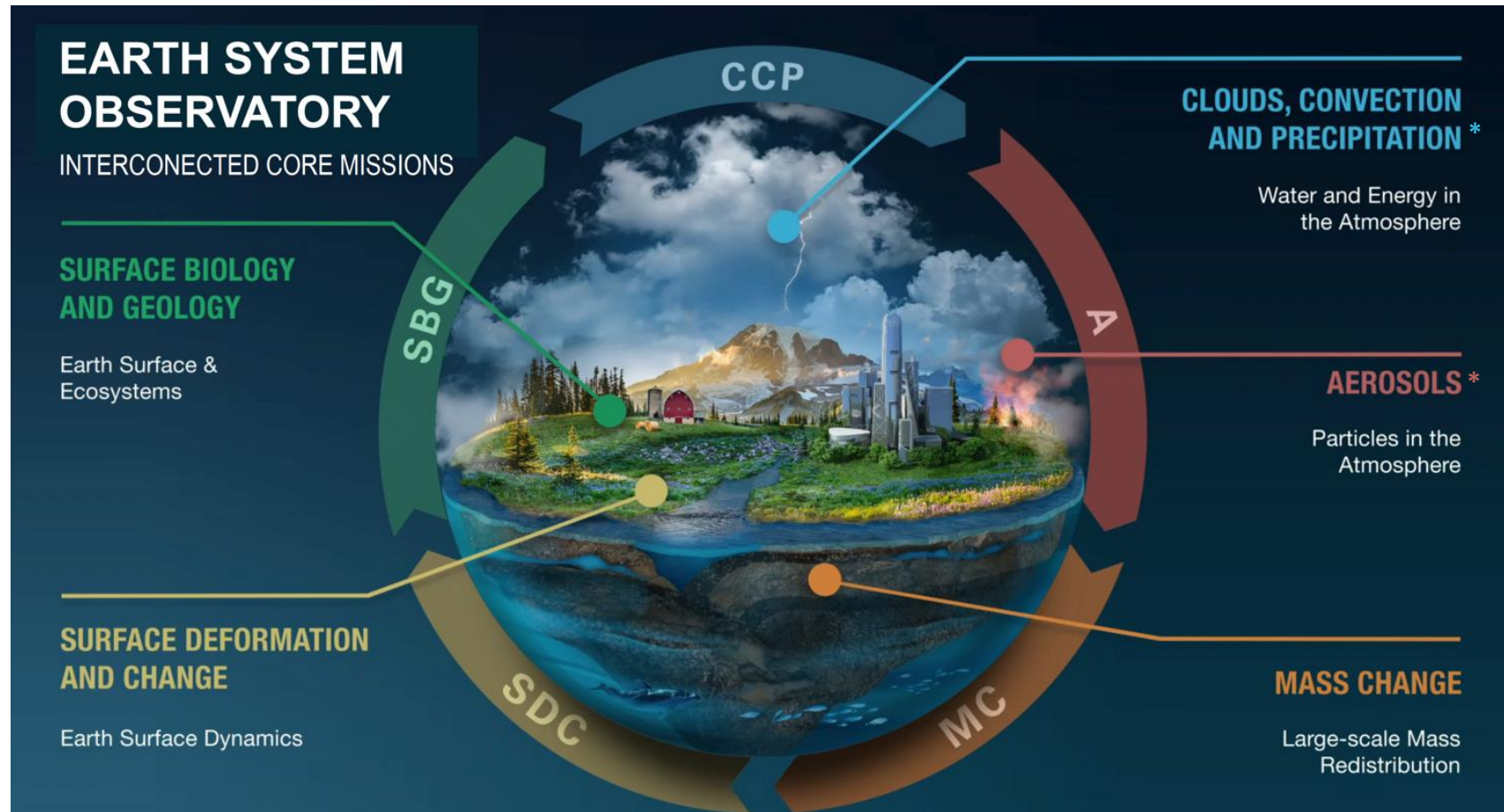
Ryan Pavlick (Jet Propulsion Laboratory, California Institute of Technology)

**and the SBG Team**



# Earth System Observatory (ESO)

The ESO follows recommendations from the 2017 Earth Science Decadal Survey.  
Surface Biology and Geology (SBG) is one of the core ESO missions.



[Credit: NASA]

\*Aerosols and Clouds, Convection, and Precipitation have been combined into a single Atmosphere Observing System (ASO) mission







# Research Objectives and Priorities

## HYDROLOGY



H-1. How is the water cycle changing?

H-2. How do anthropogenic changes in climate, land use, water use, and water storage, interact and modify the water and energy cycles locally, regionally and globally.

H-4. Hazards, extremes, and sea level rise. How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events.

## WEATHER



W-3. How do special variations in surface characteristics (influencing ocean and atmospheric dynamics, thermal inertia and water) modify transfer between domains?

## ECOSYSTEMS AND NATURAL RESOURCES



E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?

E-2. What are the fluxes of carbon, water, nutrients, and energy between ecosystems and the atmosphere, the ocean, and the solid Earth, and how and why are they changing?

E-3. Fluxes within ecosystems. What are the within ecosystems, and how and why are they changing?

## CLIMATE



C-3. How large are the variations in the global carbon cycle and what are the associated climate and ecosystem impacts?

## SOLID EARTH



S-1. How can large-scale geological hazards be accurately forecast in a socially relevant time frame?

S-2. How do geological disasters directly impact the Earth system and society following an event?

**SBG: DECADAL SURVEY MOST AND VERY IMPORTANT RESEARCH OBJECTIVES ACROSS ALL FIVE DS FOCUS AREAS**







# Applications Objectives and Priorities



## AGRICULTURE, FOOD SECURITY AND SURFACE WATER MANAGEMENT

Improve “crop per drop” by assessing vegetation water stress over irrigated agriculture

Improve water supply management through better characterization of snow properties and estimated reservoir inflows

Reduce the impacts of drought, such as crop loss and famine, on global scales



## WATER QUALITY AND COASTAL ZONES

Support early detection of and response to harmful algal bloom formation

Protect sensitive aquatic habitats by monitoring/reducing water pollutant loading, particular in coral reefs and other sensitive ecosystems

Water surface temperature and impacts on marine biodiversity



## CONSERVATION

Support biodiversity understanding and protections by mapping invasive species composition, structure, distribution; support removal and restoration efforts

Monitoring of endangered species habitat; provide alerts of disease mortality of impacted vegetation, including insect infestation

Biodiversity hotspots and priority conservation areas, 30 x 30 plans



## WILDFIRE RISK AND RECOVERY

Fuel mapping (cover type, extent, status) for wildfire danger management

Post fire severity assessment and recovery, including prediction of areas with higher likelihood of debris flows



## DISASTERS AND NATURAL HAZARDS

Detect and track oil spill events and

Support active fire mapping and response

Improve mitigation of heat wave events for vulnerable populations



## GEOLOGY APPLICATIONS

Mineral mapping for exploration efforts and reduction of environmental hazards

Forecast aviation hazards and support emergency response for volcanic eruptions

Landslide risk assessment with improved substrate map land cover maps

**SBG: DECADEAL SURVEY APPLICATION OBJECTIVES ACROSS ALL FIVE DS FOCUS AREAS**



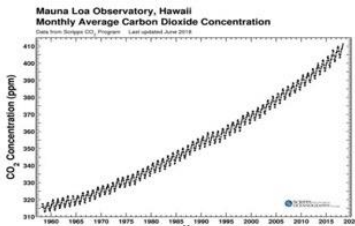
# SBG: KEY RESEARCH AND APPLICATIONS REQUIREMENTS



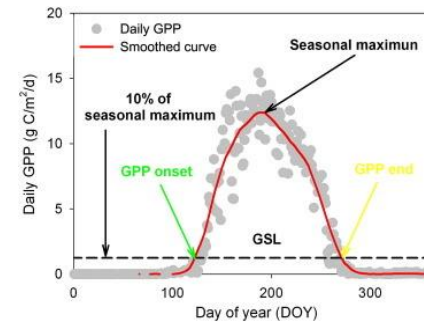
**COVERAGE:** The system must provide **global coverage** to address the global scope of the science including the coastal ocean and inland waters.



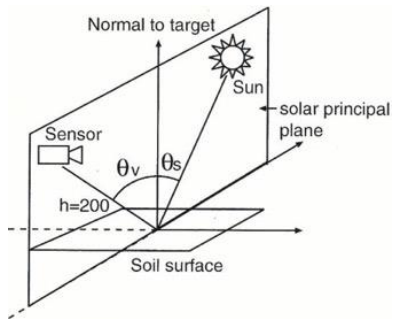
**SPATIAL RESOLUTION:** The observing system must provide **high spatial resolution** (30 and 60 m for VSWIR and TIR)



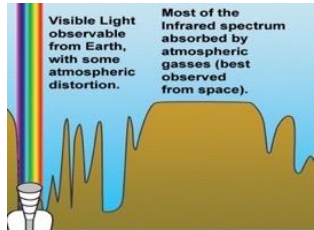
**STABILITY AND DURATION:** Measurements must be able to detect **long term changes** for addressing dynamics of the Earth System.



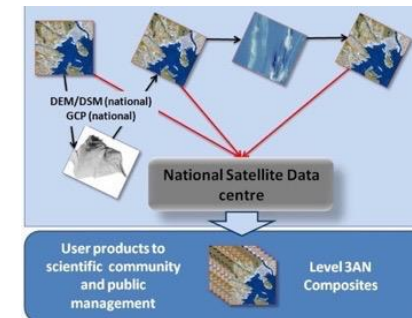
**REVISIT:** The SBG observing system temporal resolution must be adequate to capture **synoptic and seasonal variation** as well as observe **rapid or transient changes** related to Earth system events such as fires, landslides, volcanic activity and anthropogenic incidents.



**GEOMETRY:** The system's orbit must allow for **consistent sun-sensor geometry** for consistency in retrievals and for calibration and validation, and provide for global coverage, as above (polar orbit).



**RANGE, RESOLUTION AND SENSITIVITY:** Visible to Shortwave Infrared (**VSWIR; 400-2500 nm**) imaging spectroscopy and multi-spectral thermal infrared (**TIR; 4 - 12  $\mu$ m**) measurements to observe "diversity" in ecosystem function. Radiometric performance driven by aquatic targets.

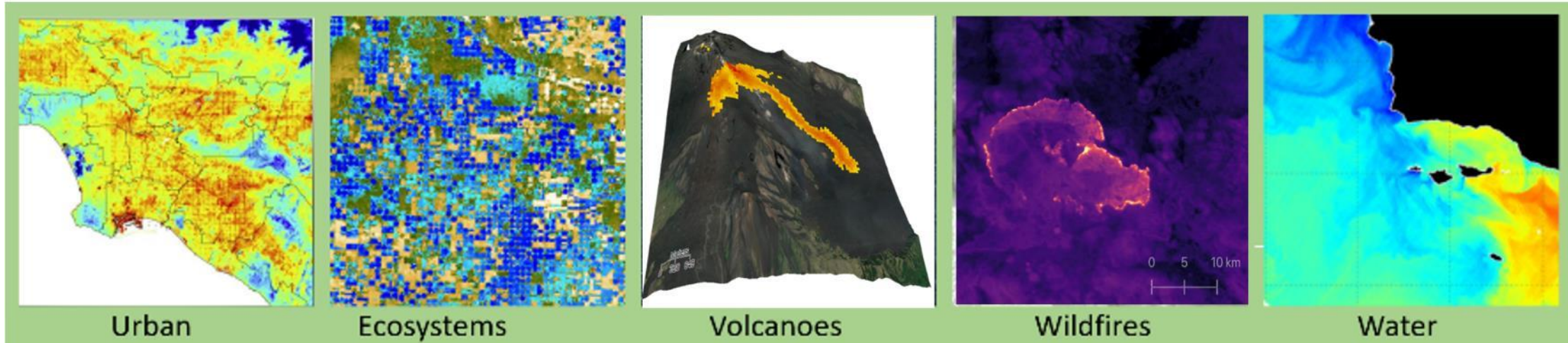


**LATENCY:** **Low latency**, the time between an event and data access, must be low enough to support time-sensitive applications,  $\leq 24$  hours.



# Objectives and priorities - distillation

- Key Decadal Survey Questions were clarified and expanded by R&A community in 5 areas:



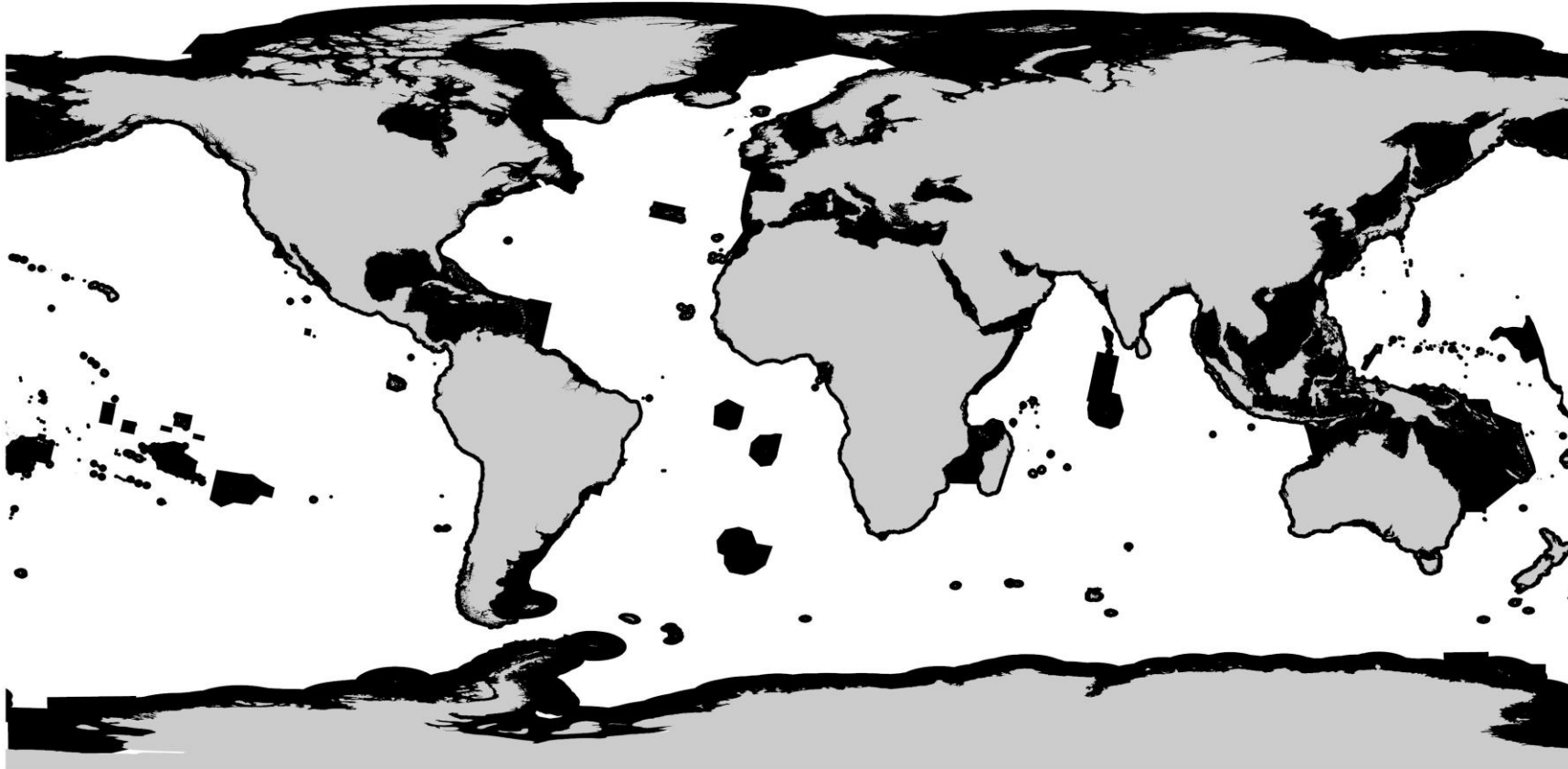
- |   |   |  |  |   |
|---|---|--|--|---|
| <ul style="list-style-type: none"> <li>• VNIR 30m</li> <li>• 2 VNIR Bands</li> <li>• High spatial resolution</li> <li>• Frequent revisit</li> </ul> | <ul style="list-style-type: none"> <li>• VNIR 30m</li> <li>• 2 VNIR Bands</li> <li>• High spatial resolution</li> <li>• Frequent revisit</li> </ul> | <ul style="list-style-type: none"> <li>• VNIR 30 m</li> <li>• High 3-5 um saturation</li> <li>• TIR band placement for SO<sub>2</sub></li> </ul> | <ul style="list-style-type: none"> <li>• High 3-5 um saturation</li> <li>• MIR band placement for FRP</li> </ul> | <ul style="list-style-type: none"> <li>• 2 longest TIR bands for split window</li> <li>• High sensitivity and accuracy for water temperature</li> </ul> |
|---|---|--|--|---|

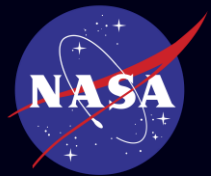
Different research areas have different requirements, some unique, some common



# Observing Requirements

Developed Universal Mask – Combination of SBG, TRISHNA and LSTM Masks  
Universal Mask





**SBG-TIR**  
Wide-swath TIR Imager  
and VNIR Camera



**SBG-VSWIR**  
Wide-swath  
VSWIR Spectrometer





**Bands:** 6 LWIR, 2 MWIR, 2 VNIR

**GSD:** TIR:  $\leq 60/93$ , VNIR:  $\leq 30/52$

**Revisit:**  $\leq 3$  days

**Swath:** 935 km

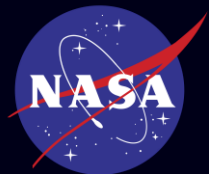
**Overpass time:** 12:30

**Accuracy:** 0.5 K

**NeDT:**  $< 0.2$  K

**Coverage:** Land and Coastal

**Latency:**  $\leq 24$  hours for select regions



**SBG-TIR**

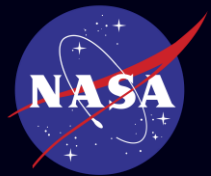
Wide-swath TIR Imager  
and VNIR Camera



**SBG-VSWIR**

Wide-swath  
VSWIR Spectrometer





**SBG-TIR**  
Wide-swath TIR Imager  
and VNIR Camera



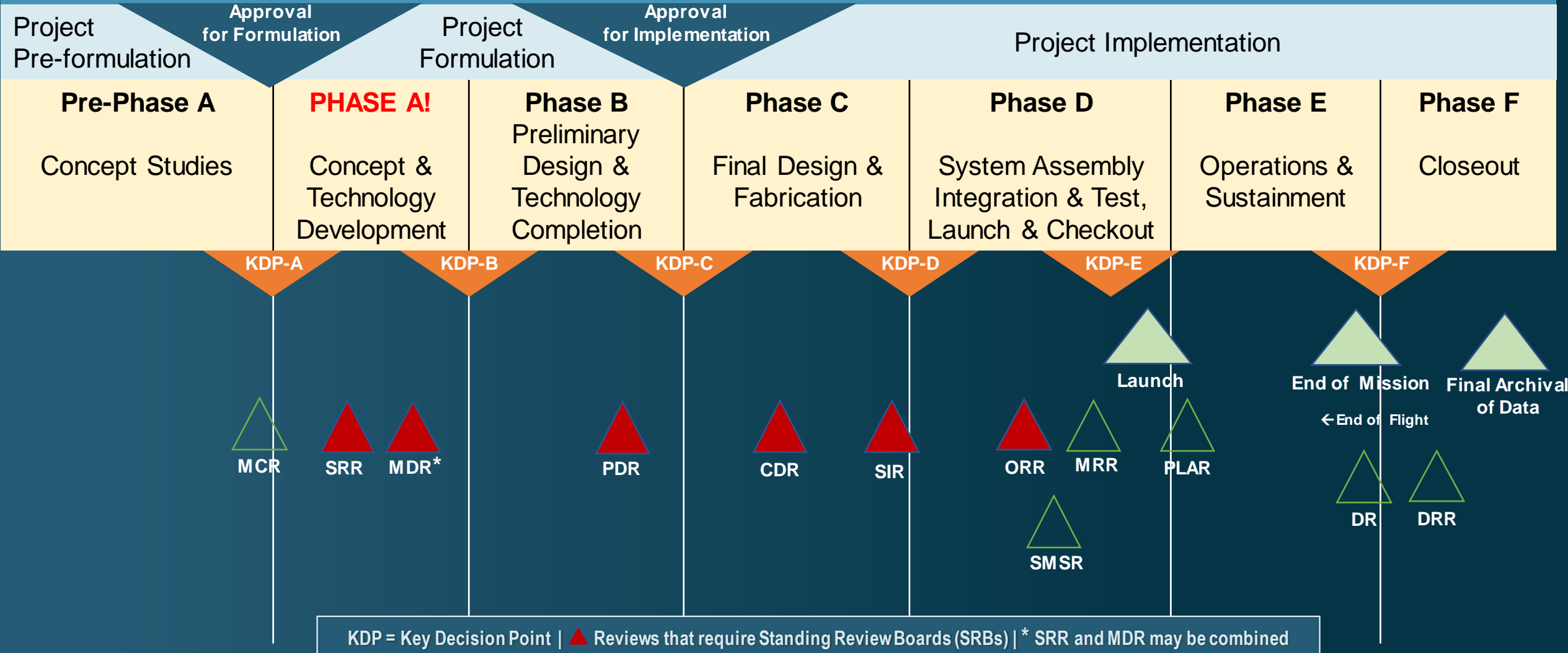
**SBG-VSWIR**  
Wide-swath  
VSWIR Spectrometer

**Range:** 380-2500nm  
**Resolution:** 10 nm  
**GSD:** 30m at nadir  
**Revisit:** 16 days  
**Swath:** 185 km  
**Overpass time:** 11:30  
High SNR and uniformity  
**Coverage:** Land and Coastal



# NASA Life-Cycle Phases

## Project Life Cycle



# SBG on-orbit collaborations

ESA LSTM  
TIR (2)

NASA SBG VSWIR

NASA/ASI SBG  
TIR+VNIR

CNES/ISRO  
TRISHNA TIR

ESA CHIME  
VSWIR (2)



Data  
Harmonization





# SBG Mission R&A Products Derived from VSWIR and TIR Observations

Land and water-leaving reflectance

Surface temperature and emissivity

Cloud Mask

Surface Type

Fractional Cover

- VSWIR-derived
- TIR-derived
- VSWIR & TIR-derived

Snow Physics

Plant Functional Traits

Evapotranspiration Suite

SBG L2+ Products

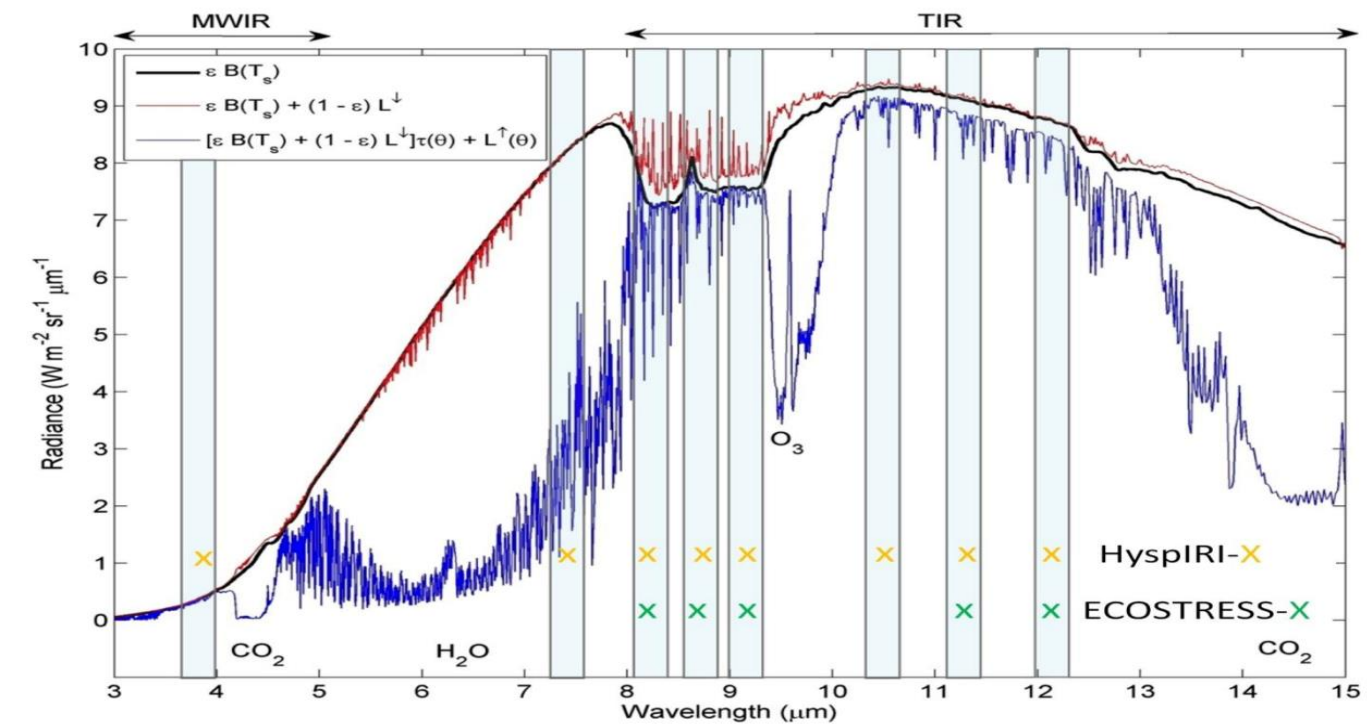
Surface Composition

High Temperature Features

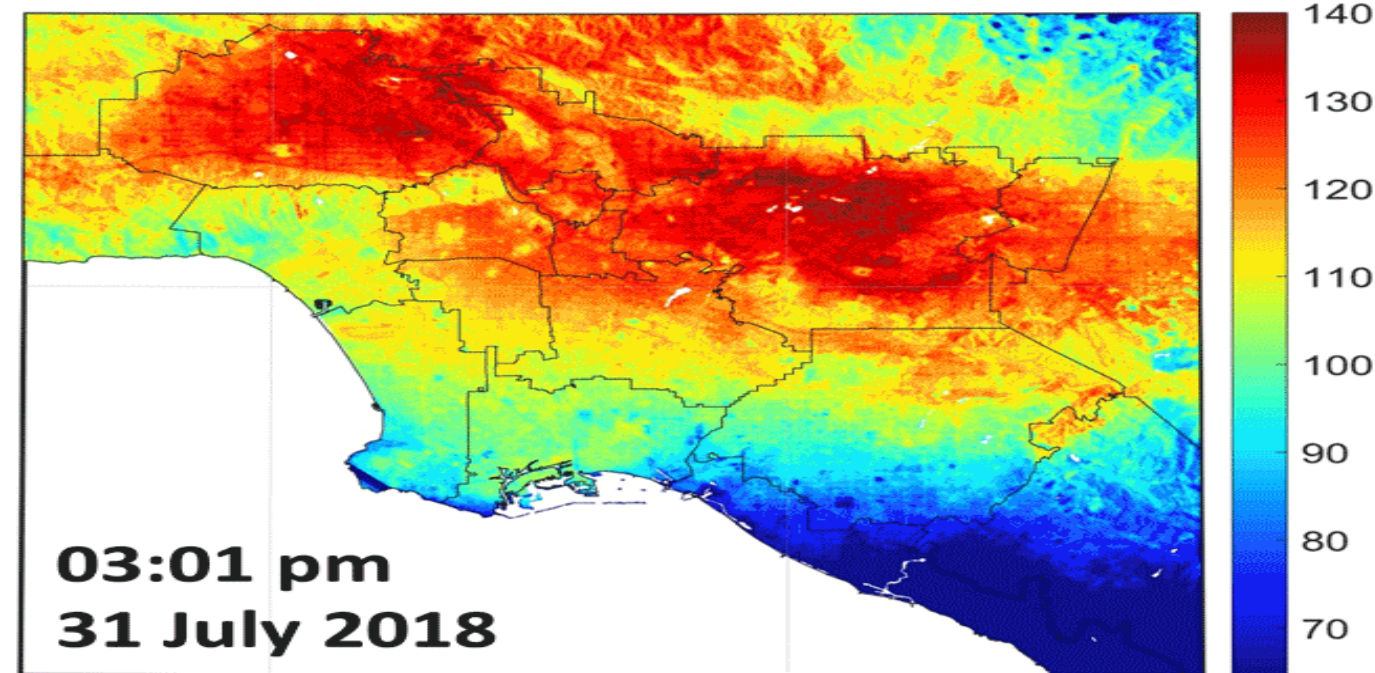
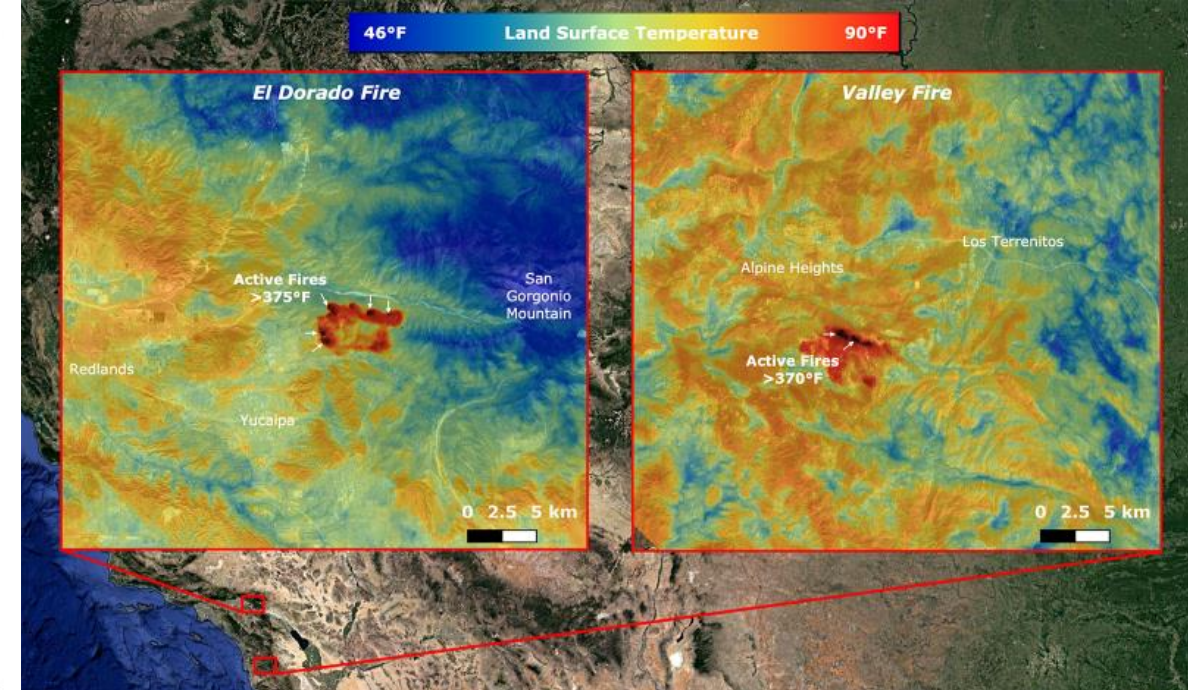
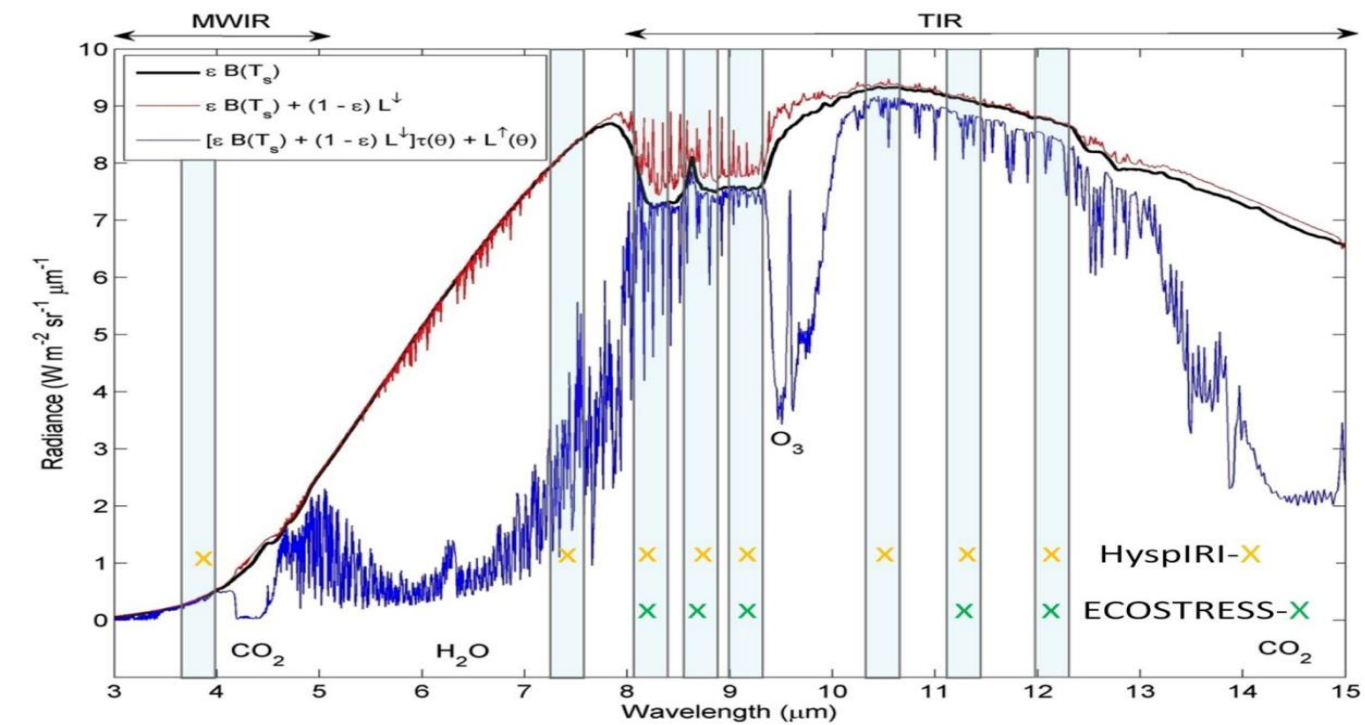
Phytoplankton Dynamics

Benthic Cover

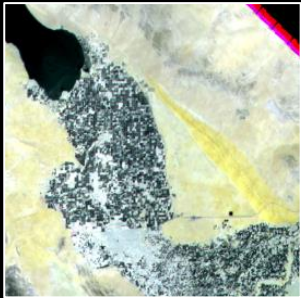
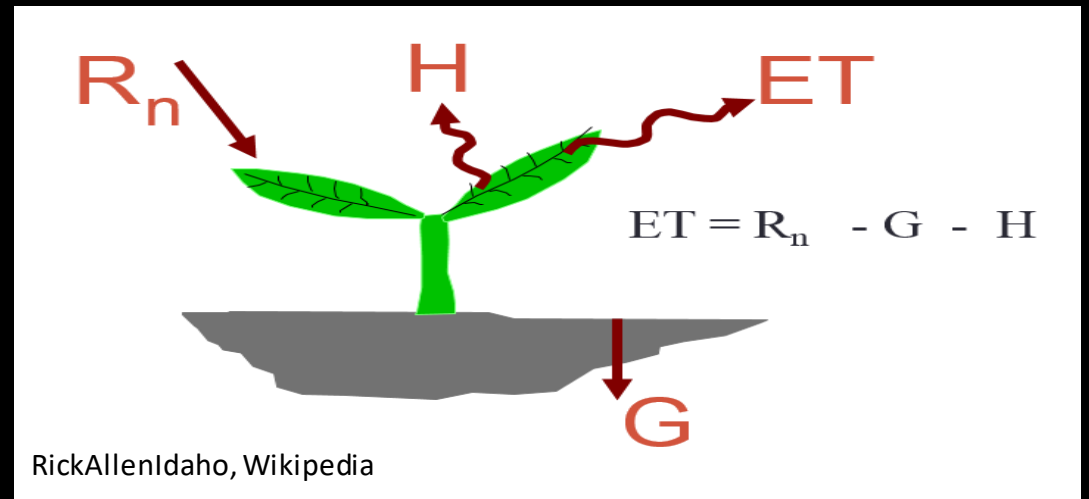
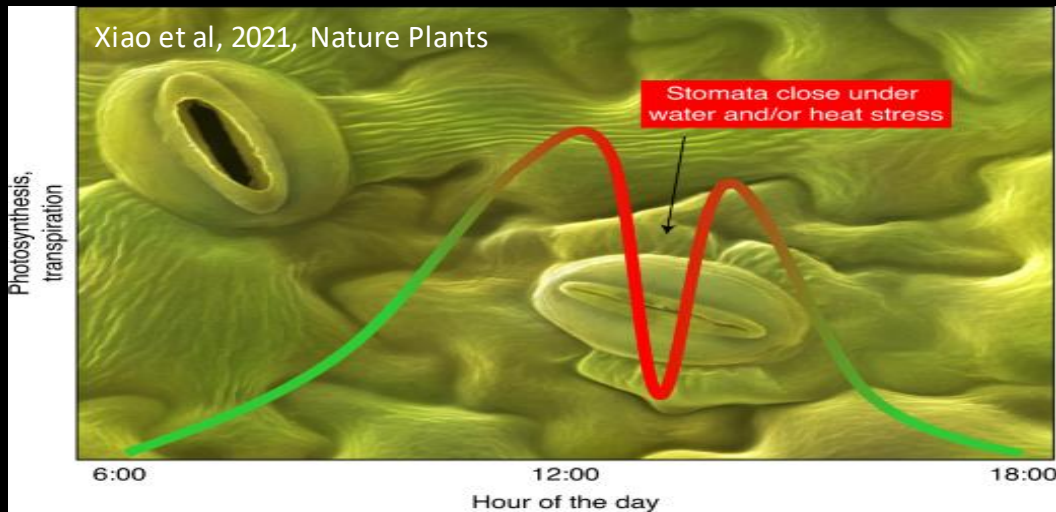




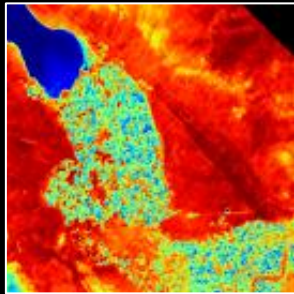








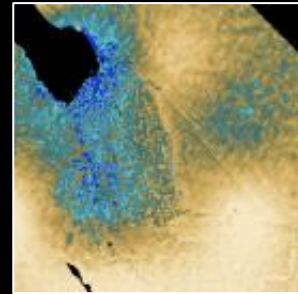
Radiance



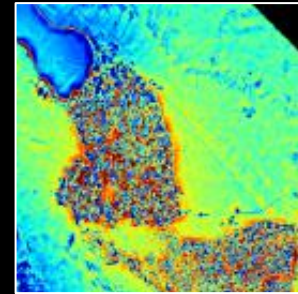
Surface Temperature



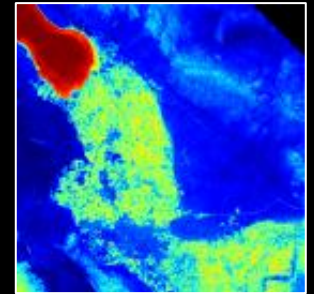
NDVI/Albedo



Soil Moisture



Meteorology



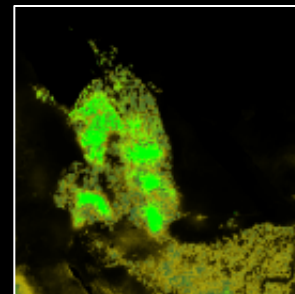
Surface Energy Balance



Evapotranspiration



Evaporative Stress Index

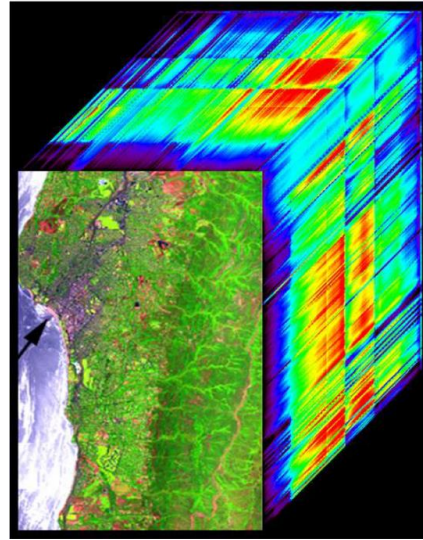


Water Use Efficiency

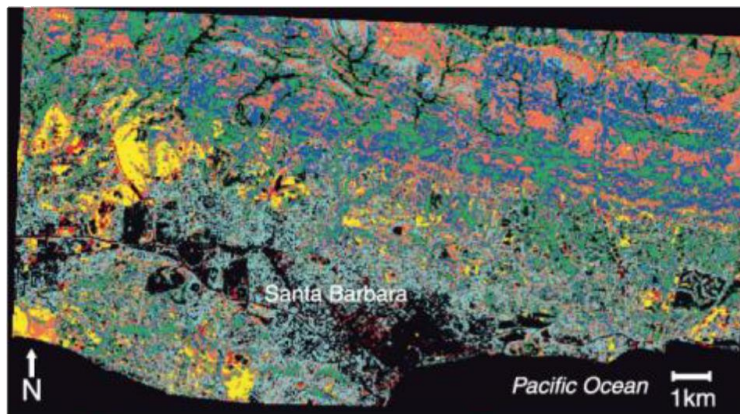


Calibrated  
Image Cube

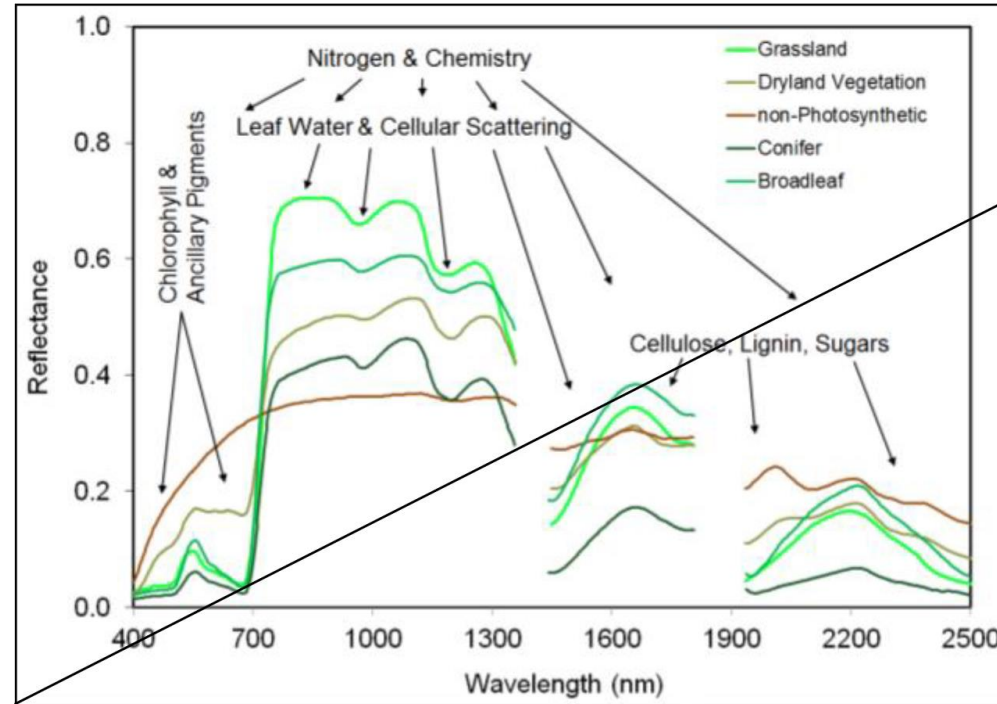
# 100's of Parallel Spectrometers



Ecosystem  
Species Map



Adenostoma fasciculatum	Quercus agrifolia
Ceanothus megacarpus	Grass
Arctostaphylos spp.	Soil

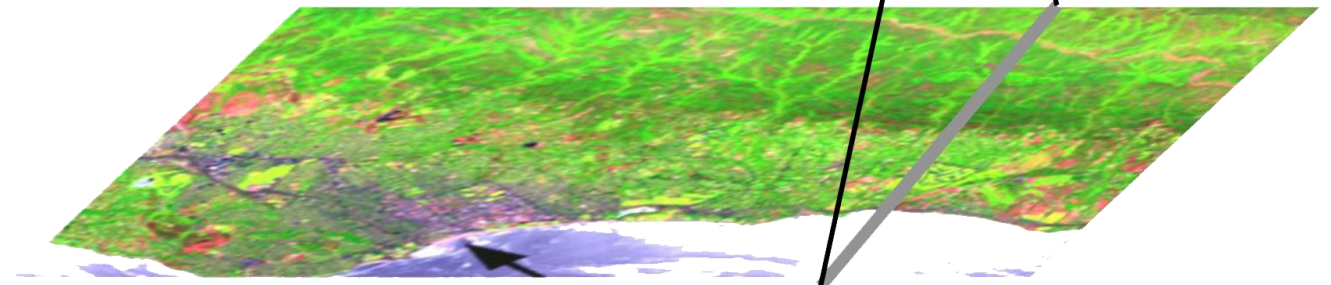


Detector Array

Spectrometer

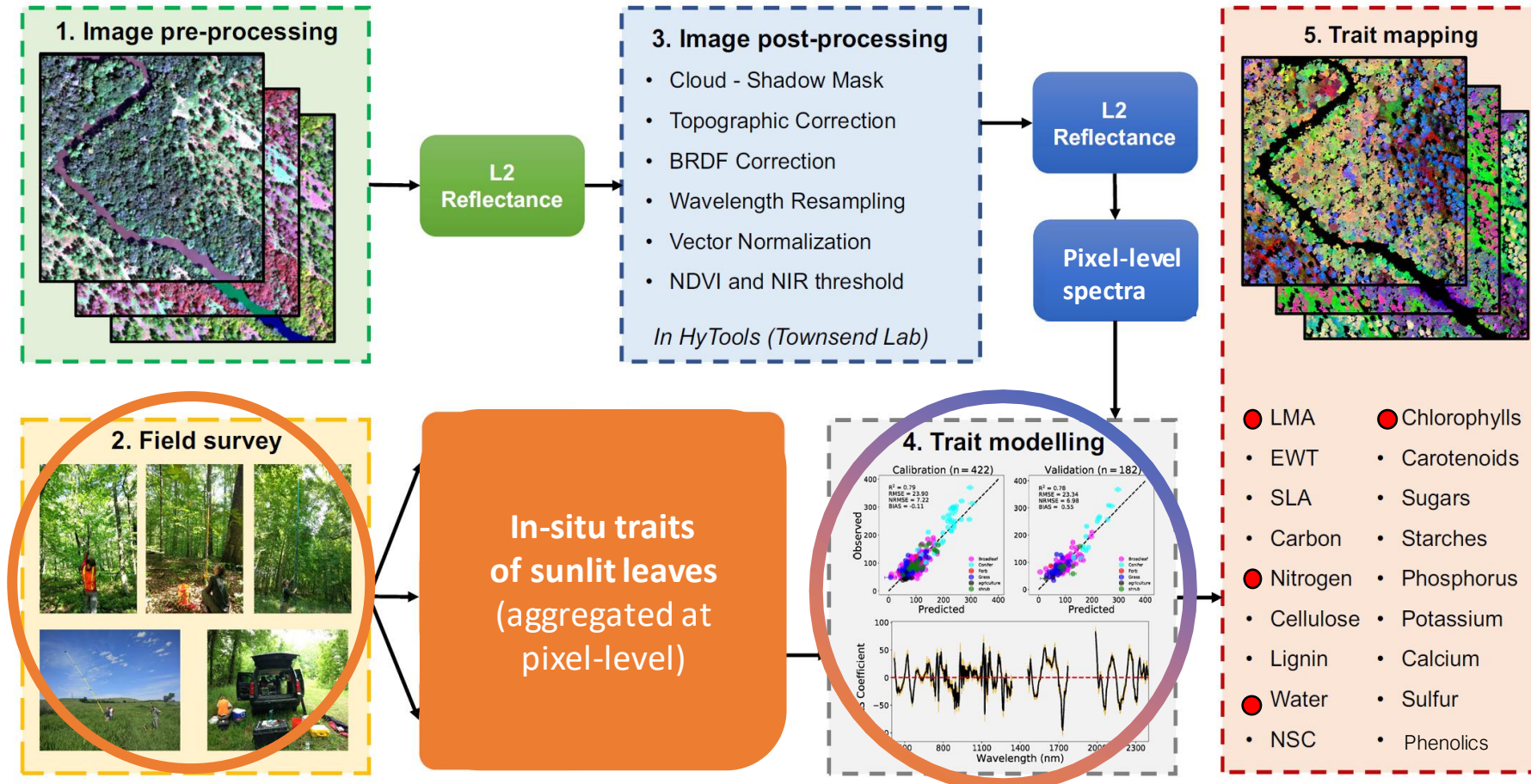
Slit

Telescope





# Progress towards large-scale trait mapping



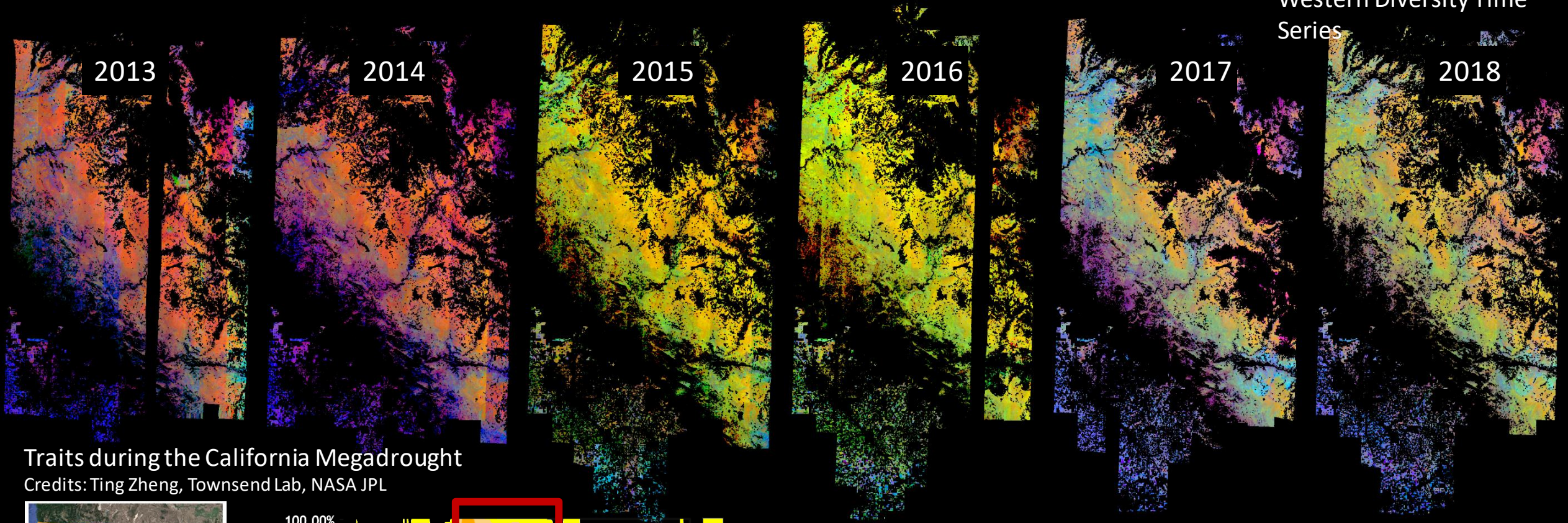
**Fig. 2** Trait mapping workflow using NEON AOP images and field data. LMA, leaf mass per area; EWT, equivalent water thickness; SLA, specific leaf area; NSC, nonstructural carbohydrate.

Adapted from Wang et al. (2020) *New Phytologist*; Queally et al (2022); Zheng et al. (in preparation)



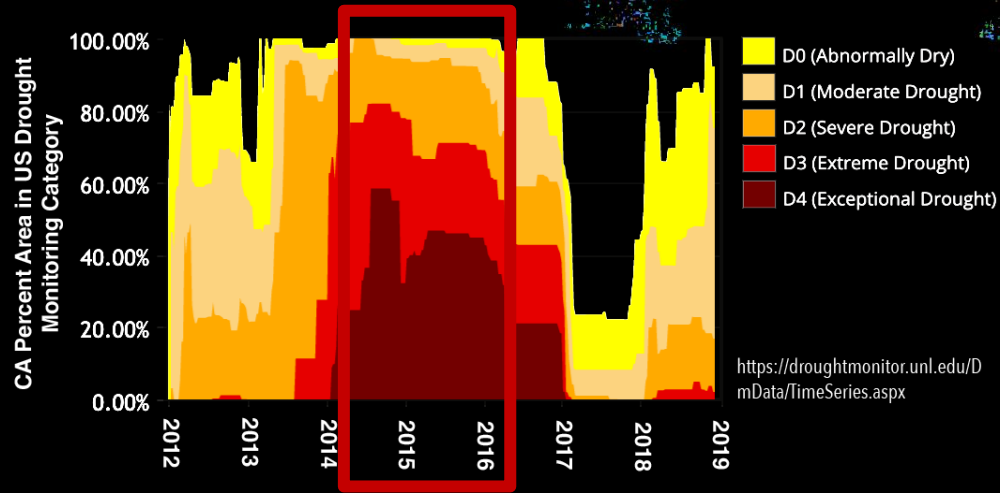
# Functional Traits through Time

NASA JPL AVIRIS Classic  
Western Diversity Time  
Series



Traits during the California Megadrought

Credits: Ting Zheng, Townsend Lab, NASA JPL



Nitrogen  
Productivity & Growth



Leaf Mass  
Per Area



Structure & Longevity

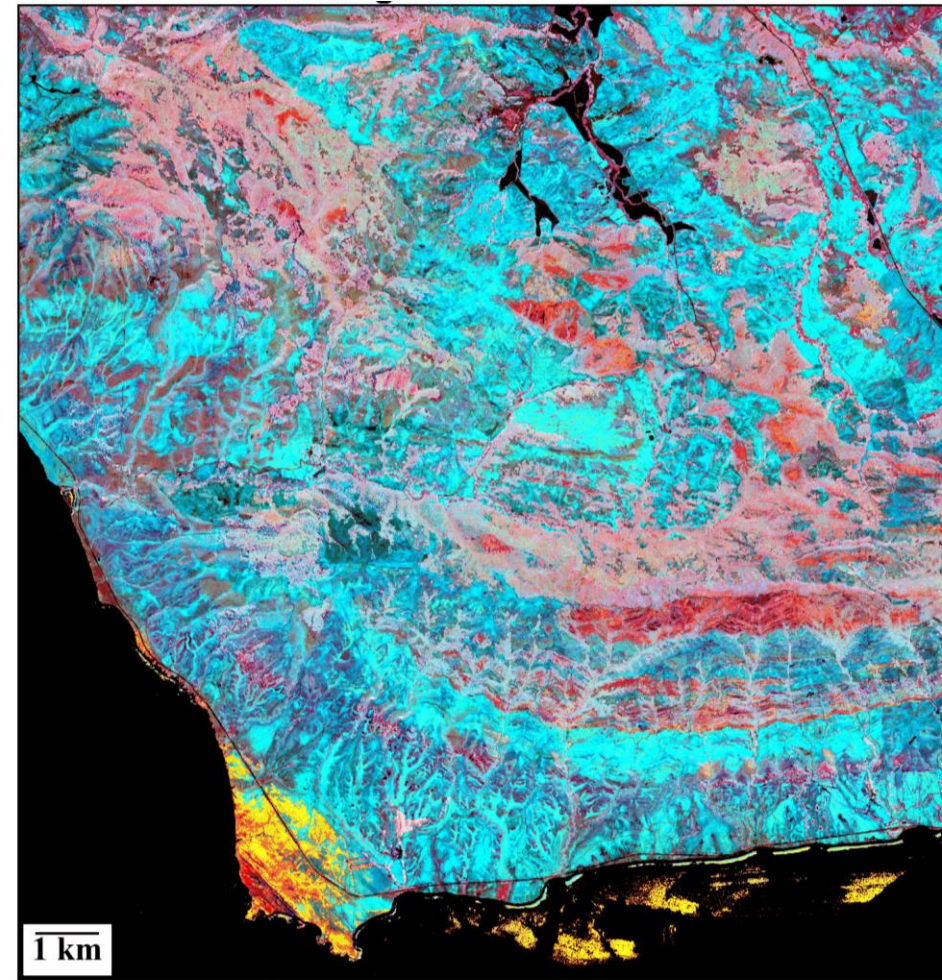
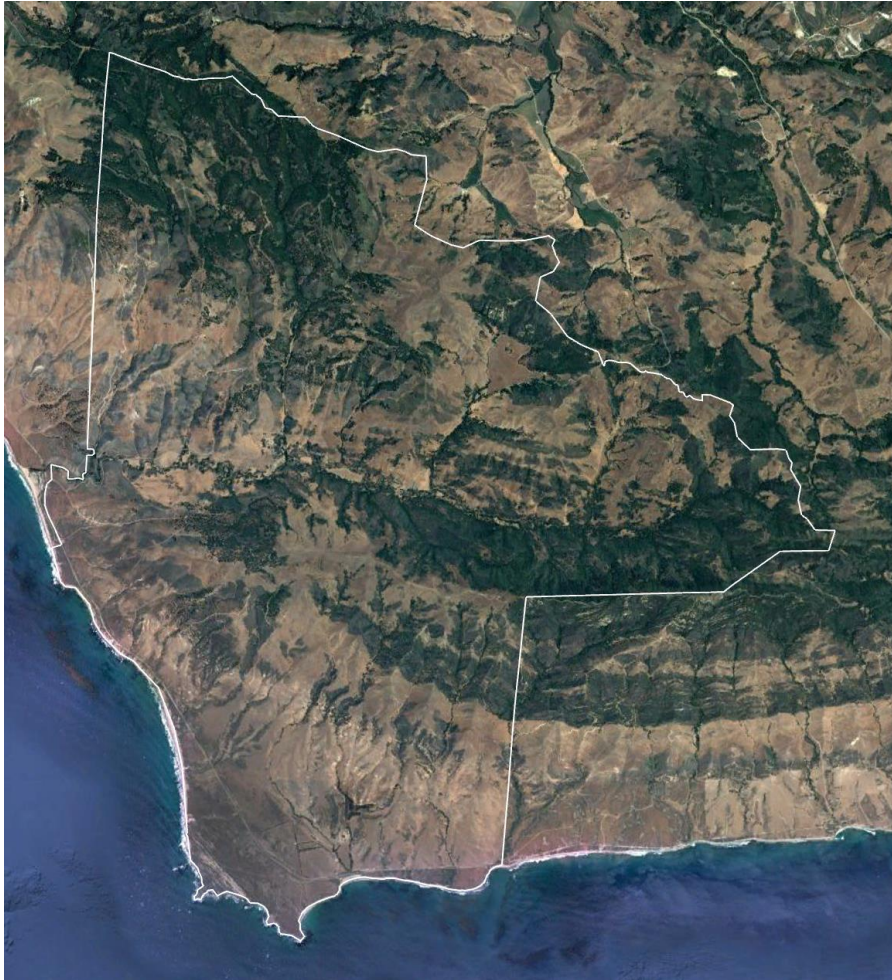
Non-Structural  
Carbohydrates  
Maintenance







# Sub-seasonal trait dynamics

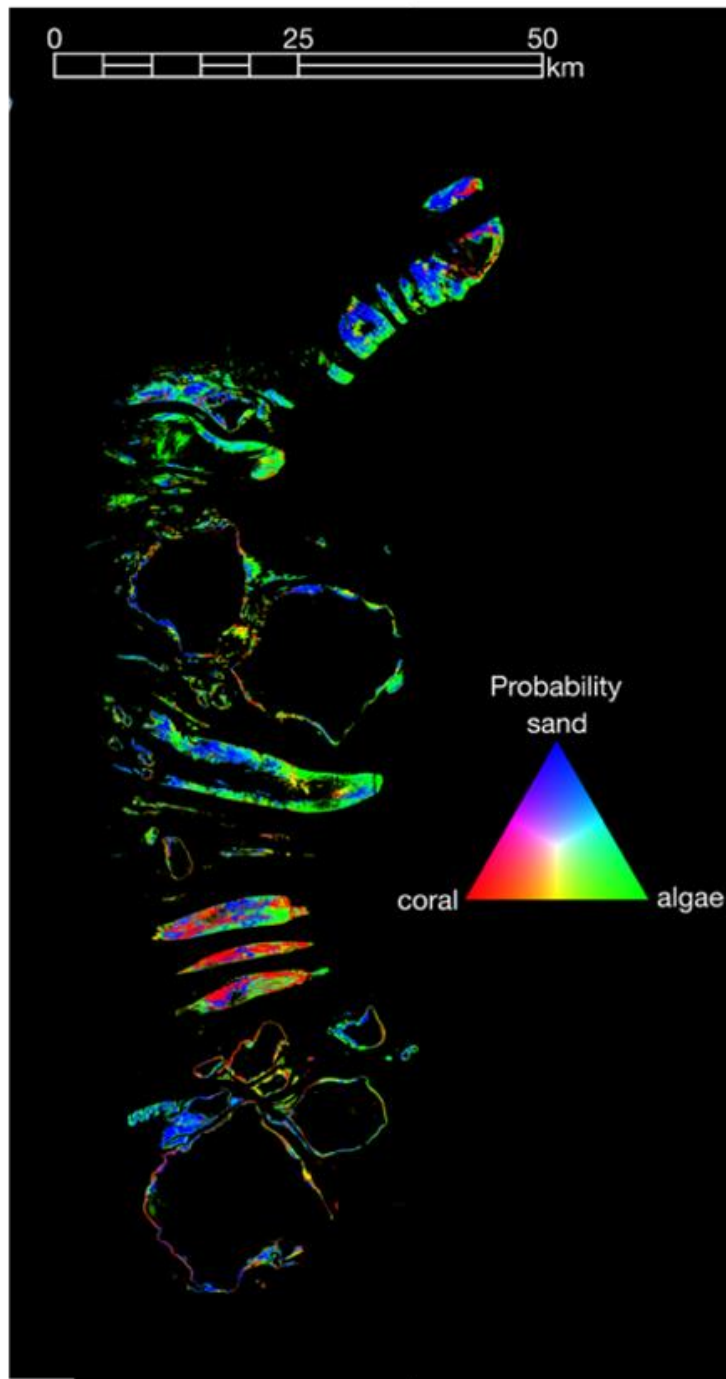
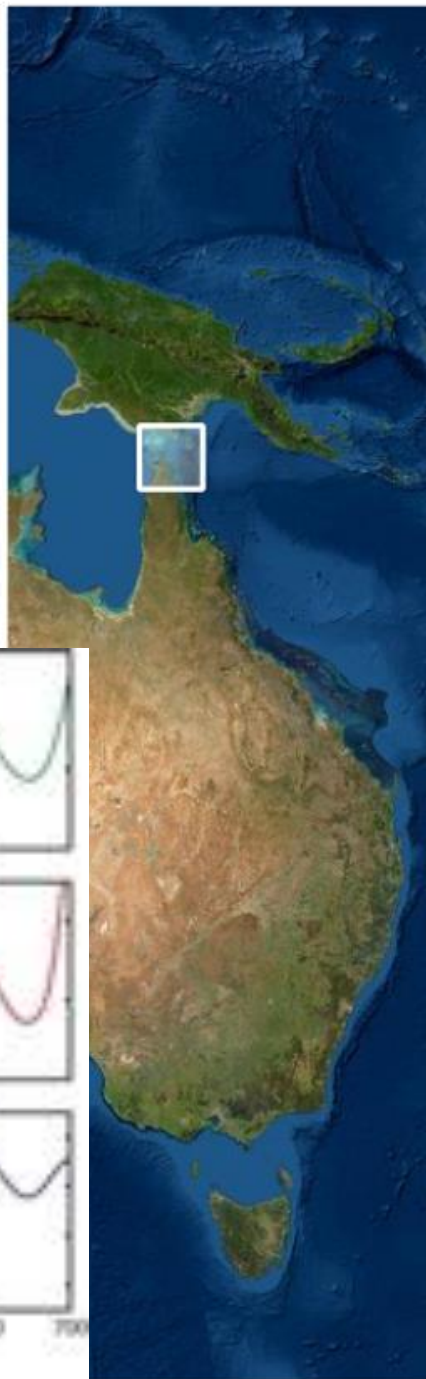
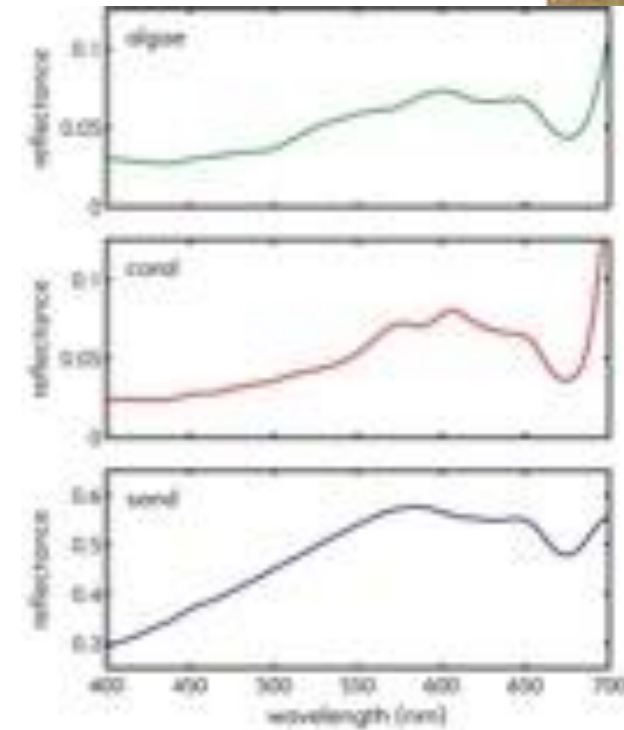


Vegetation phenology captured at unprecedented temporal, spectral, and spatial resolution gives us incredible insight into the distribution & seasonality of vegetation functional characteristics





# SBG Benthic Cover: Coral reefs

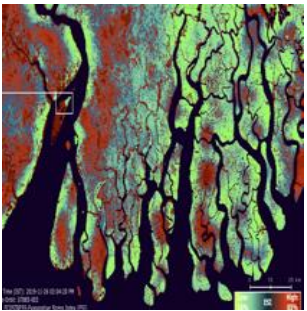


Figures: Michelle Gierach and CORAL team

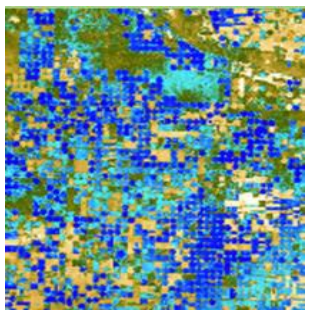




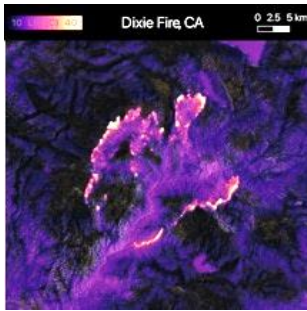
# SBG Research Themes



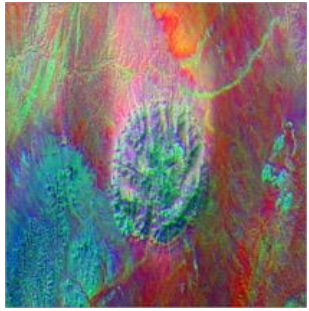
Ecosystem management



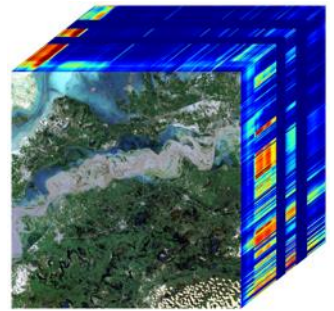
Agricultural water use and management



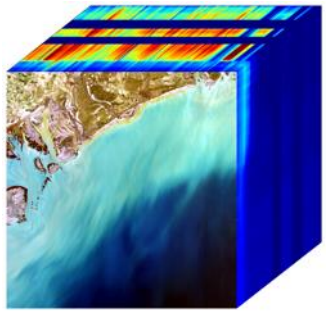
Wildfire behavior



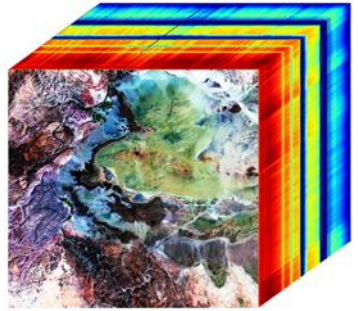
Strategic minerals



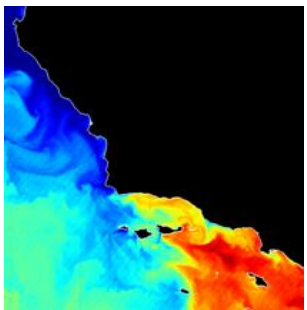
Natural hazards



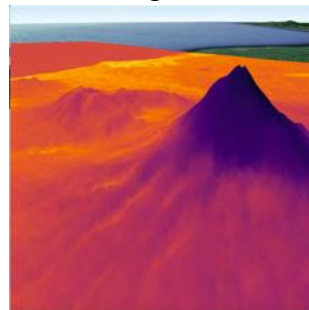
Water quality, harmful algal blooms



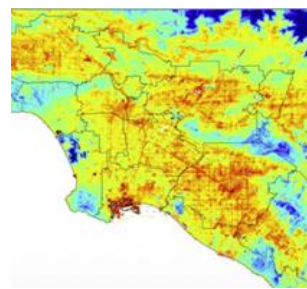
Minerals



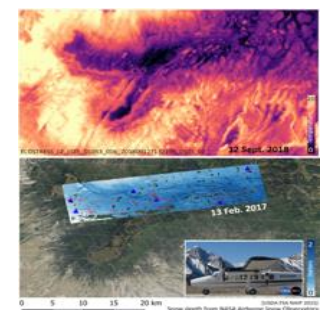
Water temperature and aquatic health



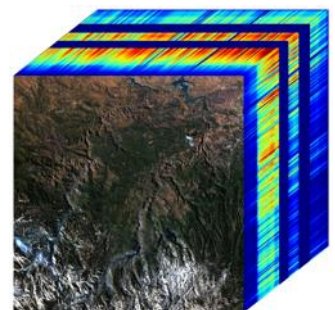
Volcano risk and hazards



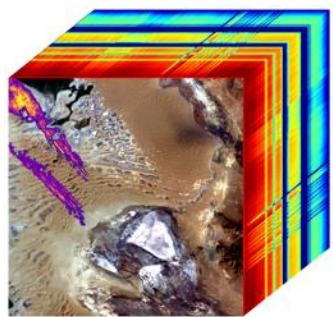
Urban heat and Public health



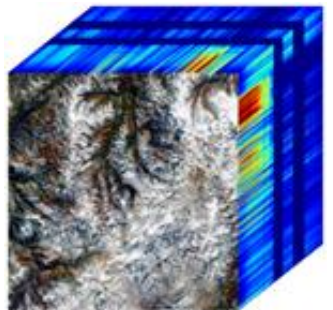
Mountain snowmelt and water resources (snow temperature)



Fire risk and management



Greenhouse Gas Emissions, point sources



Mountain snowmelt and Water resources (Snow albedo)

ECOSTRESS Thermal Infrared + EMIT VSWIR Imaging Spectroscopy







# SBG Research Themes

**EMIT:** [emit.jpl.nasa.gov](https://emit.jpl.nasa.gov)

**ECOSTRESS:** [ecostress.jpl.nasa.gov](https://ecostress.jpl.nasa.gov)

**SBG:** [sbg.jpl.nasa.gov](https://sbg.jpl.nasa.gov)

**[sbg@jpl.nasa.gov](mailto:sbg@jpl.nasa.gov)**

- Ask questions
- Join our mailing list
- Join open working groups
- Join the SBG Community Slack
- Inquiry about SBG internship opportunities

Upcoming webinar in Aug/Sep and an in-person community workshop in late 2023/early 2024

